

WO 01/75922

32/Pr 12

9/980299
 JC13 Rec'd PCT/PTO 29 NOV 2001
 PCT/GB01/01425

1

Ins
PI ~~Data Input Device~~

5 The present invention relates to a data input keyboard device for a computer or similar electronic device, particularly where the keyboard device is fabricated from textile fabrics.

Flexible keyboards, particularly in the form of membrane keyboards, are known. Such keyboards comprise one or more sheets of a plastic membrane material such as MylarTM or the like, to which electrical contacts are applied, commonly in the form of printed silver-loaded ink or a similar
 10 conductive material. The electrical contacts are specifically configured so as to enable an electrical output to be detected in response to key-presses on the membrane keyboard. Accordingly, the precise position and, hence, the identity of the actual key pressed can be determined.

A problem with known membrane keyboards is the inherent plasticity
 15 of the membrane material and the high internal friction that occurs between constituent layers during bending. As a consequence, the durability and flexibility of membrane keyboards is compromised.

According to a first aspect of the present invention there is provided a foldable alpha numeric keyboard device configured to input data items into a
 20 computer or similar processing device, said keyboard device comprising a first electrically conductive fabric sheet and a second electrically conductive fabric sheet; an interface circuit configured to supply voltages to and receive outputs from said keyboard; wherein said keyboard is configured to produce an output in response to a mechanical interaction and said interface circuit is
 25 arranged to respond to said mechanical interaction and to provide a data item to said computer or similar processing device.

09980299 12001

5

5 *Figure 1a* shows an alternative fabric to that of *Figure 1*, fabricated using a knitting process;

10

15

15 *Figures 5A and 5B show cross-sectional views through alternative key registration devices.*

20

Figures 7A and 7B show separately the conductive layers **401** and **402** of Figure 4;

25

WO 01/75922

PCT/GB01/01425

3

Figure 9 shows a detailed view of the interface circuit of *Figure 8*;

Figure 10 details an example of a pressure/location detection circuit that is incorporated into the interface circuit of *Figure 9*;

Figures 11A and *11B* detail schematically the pressure measurements that can be made by the location/pressure detection circuit identified in *Figure 10*;

Figure 12 is a flow chart illustrating a mode of operation performed by the PIC16C711 processor shown in *Figure 10*;

Figure 13 is a flow chart detailing the initialisation procedure performed by the PIC16C711 processor shown in *Figure 12*;

Figure 14 is a further flow chart detailing the configurations of the PIC16C711 processor for the collection of Z value data as indicated in step 1202 of *Figure 12*;

Figures 15A and *15B* detail schematically the X and Y positional co-ordinate measurements that can be made by the location/pressure detection circuit identified in *Figure 10*;

Figure 16 is a flow chart detailing a further mode of operation of the PIC16C711 processor;

Figure 17 is a flow chart detailing the configuration of the PIC16C711 processor for the collection of X, Y co-ordinate positional data and Z axis data as indicated in step 1601 of *Figure 16*;

Figure 18 Shows an alternative alpha-numeric keyboard, to that of *Figure 8*;

Figure 19 provides an exploded view of the layered structure of the device shown in the *Figure 18*;

T022T 6620550

Figure 21 shows a further alternative alpha-numeric keyboard embodying the present invention;

Figure 23 shows a further alternative alpha-numeric keyboard embodying the present invention;

Figures 25A and 25B show separately the conductive layers 2401 and 2402 of Figure 24.

Figure 27 shows the keyboard device shown in Figure 23 in use.

A woven fabric is shown in *Figure 1* of a type suitable for application in an alpha-numeric keyboard made in accordance with the present invention. The woven fabric has warp yarns **101** made from single filaments of carbon coated nylon-6, available from BASF under the trademark "RESISTAT" and identified by the designation F901. F901 is a fibre produced primarily for use in static dissipation applications in fabrics. Many different sizes of filament may be employed, dependant upon the requirements of an application, and in this example the size of the filaments is twenty-four decitex, (24 grams per

WO 01/75922

PCT/GB01/01425

5

10,000m) presenting a diameter of fifty-two micrometers.

Weft fibres **102** are fabricated from a polyester yarn of similar dimensions to the warp. These polyester weft yarns are non-conductive such that the resulting fabric is conductive along the warp, in direction **103** but not
5 conductive in the orthogonal weft direction, as illustrated by arrow **104**. Thus, due to the nature of the weave of the material, each conductive warp yarn **101** is separated from adjacent conductive yarns, even when flexed, due to the undulating nature of the weft yarn **102**. Thus, the fabric is composed of a plurality of lengths of conductive yarn and a plurality of lengths of insulating
10 yarn, such that each length of conducting yarn is electrically isolated from adjacent lengths of conducting yarn.

As used herein, a yarn should be understood to include a spun thread having many fibres or a continuous fibre, possible extruded from plastic etc. Thus, in this example, each length of the warp yarns is a continuous thread
15 whereas the wefts **102** are spun from a plurality of threads.

An alternative to the fabric of *Figure 1* is shown in *Figure 1A*. *Figure 1A* provides a detailed view of a fabric **111** produced by a knitting process. Such a construction may be achieved by using either a warp knit or a weft knit process. The knitted fabric **111** is produced by knitting together lengths
20 of conductive yarn **112**, **113**, **114** and lengths of non-conducting yarn **115**, **116**, **117** in a machining process. Therefore, in a similar manner to the fabric of *Figure 1*, the fabric of *Figure 1a* contains lengths of conducting yarn (e.g. **113**) that are electrically isolated from adjacent conducting yarn (e.g. **112** and **114**) by non-conducting yarn (e.g. **116** and **117**).

25 The knitted fabric thus provides a layer having conductivity in one direction along the layer, indicated by arrow **118**, which is defined by the

T0321 662550

WO 01/75922

PCT/GB01/01425

6

alternating conductive and non-conductive yarn. The layer is non-conducting in the orthogonal direction indicated by arrow 119.

Figure 2

5 In the construction of an alpha-numeric keyboard, a plurality of lengths of conductive yarn are selected for electrical connection to a conductive track. Therefore, a plurality of warp yarns, of the fabric of *Figure 1*, are electrically connected to a conductive track, as shown in *Figure 2*. In the weaving of fabric of the type shown in *Figure 1*, the warp threads are not
10 physically grouped and no additional processes need to be performed to the general weaving process. The grouping is only defined by the electrical connection. In the embodiment, all warp threads are electrically connected such that, at a boundary, a warp thread will be connected to a particular electrical connector with the adjacent thread being connected to a different connector; it being noted that adjacent warp threads are electrically insulated
15 from each other by the non-conducting weft threads. However, in an alternative embodiment, non-conductive warp threads could be introduced at group boundaries or gaps may be introduced such that some of the warp threads remain unconnected to an electrical connector. However,
20 advantages in terms of continuity exist if all of the threads are electrically connected, particularly if the device is to be used as a single conductive layer (with the individual connectors being electrically connected together) so as to minimise the introduction of discontinuities.

Conductive track 201 has a conduction portion 202 and an attachment
25 portion 203. The attachment portion 203 makes physical and electrical contact with a set of conducting warp filaments 101. The conduction portion

05980299 "12301

WO 01/75922

PCT/GB01/01425

7

202 facilitates electrical connection to external devices. The conducting tracks 201 are applied to the conductive material and an insulating substrate 204 by a printing process, using a conductive ink such as that normally used in flexible printed circuit manufacture. Alternatively the conducting tracks may be fabricated from a highly conductive material, possibly fabricated exclusively from conductive filaments, and then attached to the substrate material and the conducting material by means of a conductive adhesive, such as conductive acrylic adhesive containing metallised particles. Alternatively, the conducting tracks may be fabricated from fabric coated with conductive metals, such as silver or nickel. Material of this type is readily available and is used extensively for shielding equipment from electromagnetic interference. This too may be used in conjunction with a conductive adhesive.

Figure 3

Conductive track 201 represents one of many similar conductive tracks present within a fabricated sheet, of the type illustrated in *Figure 3*. *Figure 3* shows the first seven attachment portions 203 and 301 to 306 of sixteen present, each having respective conducting tracks printed or glued to substrate 204. In this way, there is provided sixteen conducting bands corresponding to the attachment portions. For example, the conducting bands 311 to 317 correspond to the first seven attachment portions 203, and 301 to 306. The material has a similar arrangement of attachment portions, e.g. 321 to 327, at its opposite end. Thus, in this way, it is possible for an electrical current to flow through each of the conductive bands e.g. 311, without conduction being made possible between the bands given that the

WO 01/75922

PCT/GB01/01425

8

material is not conductive in the orthogonal direction, that is along the direction of the wefts.

Figure 4

5 Two fabricated material layers **401** and **402** of the type shown in *Figure 3* form part of the seven layer device of the type shown in *Figure 4*. The top conductive layer **401** includes a conductive track assembly **404** having attachment portions making electrical contact along one side of the layer **401**, and a second conductive track assembly **405** having attachment portions forming an electrical contact along the opposing edge of the fabric layer **401**. The conductive track assemblies **404** and **405** are described in more detail in reference to *Figure 7*. The conductive warp fibres of layer **401** extend across the layer from attachment portions of the conductive track **404** to the conductive track **405** thus defining conductive columns across the layer **401**.

10 The bottom conductive layer **402** has a conductive track assembly **406** having attachment portions contacting the fabric layer along one side of the bottom conductive layer **402** and a second conductive track assembly **406a** having attachment portions contacting the fabric layer along the opposing side of the bottom conductive layer **402**. The conductive threads extend between the attachment portions of conductive tracks **406** and **406a**, and are arranged at an angle of ninety degrees to the warp threads of layer **401**. Thus, the conductive tracks in top conductive layer **401** present a plurality of conductive columns, with layer **402** presenting a plurality of conducting rows between respective attachment portions.

15

20

25

WO 01/75922

PCT/GB01/01425

9

The seven layer device also includes a central conductive layer **407** and intermediate insulating layers **408** and **409**. The central conductive layer **407** is constructed by knitting a polyester yarn of twenty-four decitex filaments having a single conductive filament twisted therein, such that the conductive filament appears relatively randomly in the completed knitted product. In addition, the central conductive layer **407** has a conductance perpendicular to the plane of the device (in the z axis) that increases as it is placed under increasing pressure thereby facilitating conduction between the layers related to the applied pressure during a mechanical interaction.

The insulating layers **408** and **409** are woven or knitted with a relatively wide spacing so as to ensure that the conductive layers are separated while at the same time allowing conduction to take place when mechanical pressure is applied. The presence of these insulating layers ensures that the overall construction may be folded and flexed or wrapped around objects without causing the two conductive layers to be brought into contact and thereby producing an erroneous contact identification.

A top insulating layer **410** is also included in the device. This is a woven layer of insulating fabric onto which a "QWERTY" keyboard outline **411** has been printed on the upper surface along with a rectangle **415** defining a touch pad area. A bottom insulating layer **412**, of woven fabric, completes the device. Layer **412** supports an array of key registration devices **413** which are arranged so that each device **413** is aligned with the centre of a QWERTY key outline on layer **410**.

In an alternative embodiment, it is possible to fabricate a device using five layers, effectively removing layers **408** and **409**. To achieve this, conducting layers **401** and **402**, or the central conductive layer **407**, are

WO 01/75922

PCT/GB01/01425

10

5 fabricated in a way such that portions of the non-conducting fibres stand proud of the conducting fibres, thereby effectively introducing a degree of insulation in the z direction. This may be achieved by using weft fibres having a larger dimension than the warp fibres or alternatively by introducing other ways of making the weft fibres stand proud.

10 In a further alternative embodiment, the device is fabricated without any layers between the two layers 401 and 402. In a similar manner to the five layered device, the layers 401 and 402 are fabricated using conducting and non-conducting fibres, such that the non-conducting fibres stand proud of the conducting fibres. The conducting fibres are thus recessed within the layers. The resulting assembly has disadvantages in use, in being more prone to outputting erroneous signals when flexed or folded. This disadvantage is minimised by increasing the depth of the recessing of the conductive fibres in each layer. However, this in turn makes the device
15 harder to activate at low pressures.

20 The advantage of such an assembly is in its simplicity of construction. In fact such an assembly can be produced in a single pass on a weaving loom in the form known as a "double cloth", where insulating weft and conducting warp form an upper portion of the fabric, and a conducting weft and an insulating warp form a lower half of the fabric. The two portions are periodically attached by the inclusion of one of the insulating yarns from either portion, in the other portion. Insulating substrate material and conducting tracks are then applied onto the outside of the resulting fabric, to complete the assembly.

25 Conducting tracks, such as track 201, are covered by an insulating adhesive tape or alternatively by a printed insulating material. The layers

05980299.12901

WO 01/75922

PCT/GB01/01425

11

shown in *Figure 4* are then assembled together, by a sewing operation, or alternatively by lamination, to form an assembled alpha-numeric keyboard.

Figure 5

5 Two of the key registration devices shown at 413 of *Figure 4* are shown in the cross-sectional view of *Figure 5*. The key registration devices 501 and 502 correspond to the keys for "2" and "Q" respectively. The devices 501 and 502 are mounted onto layer 412 below the upper layers 401, 402, 407, 408, 409 and 410. The registration devices 501 and 502 are dome-like plastic mouldings known as over-centre mouldings. The device 502 is shown 10 in its relaxed position and the layers of fabric above it are not compressed. Whereas, the device 501 is shown deformed under the pressure of a finger 503, and the upper layers of fabric 401, 402, 407, 408, 409 and 410 are compressed between the finger and the device 501. The compression of the 15 upper layers allows current to flow from layer 401 to layer 402 at that location.

Under the pressure exerted by a finger the device 501 deforms inwardly until at a certain position its resistance to deformation becomes suddenly reduced and it pops down. On release of pressure it will pop back 20 up to its relaxed position.

The devices such as 501 serve the purpose of establishing an accurate position for the compression of the fabric. This provides for reduced ambiguity as to which key press is intended by the user. In addition, the deformation of the over centre provides the user with tactile feedback in two 25 ways. Firstly, the user identifies the bump produced by the over centre as the correct location of a key. Secondly, the user feels the deformation of the over

WO 01/75922

PCT/GB01/01425

12

centre under the finger and is satisfied that the key has been pressed sufficiently firmly.

In an alternative embodiment, all key registration devices are solid plastic or silicone rubber bumps **510** mounted on layer **412** as shown in *Figure 5a*. Therefore, the devices serve the purposes of establishing an accurate position for the compression of the fabric and provide the user with tactile feedback with regard to the location of the key. Alternatively bumps **510** are mounted on the underside of top insulating layer **410**, thus negating the need for layer **412**.

In a further alternative embodiment, the key registration devices are solid bumps **511** of plastic or silicone rubber of a reduced size as shown in *Figure 5b*, such that the user does not feel them but they still provide a means of ensuring accurate positioning of compression of fabric at a key.

In another alternative embodiment the key registration devices are mounted on the uppermost conductive layer **402**, as illustrated in *Figures 5C* and *5D*. *Figures 5C* and *5D* show cross-sectional views through an alternative key registration device **521**, which forms part of an array of key registration devices in a key board. In this embodiment the construction of the alpha-numeric keyboard is similar to that previously described with reference to *Figure 4* except that the key registration devices are mounted on the upper surface of conductive layer **402** below the outer insulating layer **410**, and the key registration devices themselves have an additional feature to those illustrated in *Figure 5*, in the form of a bump **522**.

Thus the key registration devices, such as device **521**, are dome-like plastic mouldings known as over-centres, which have an integral bump located centrally on their underside. The over-centre **521** is shown in *Figure*

WO 01/75922

PCT/GB01/01425

13

5D at the start of a press by finger 523. The force applied by the finger 523 is transferred to the fabric layers 402, 408, 407, 409, 401, 412 at the circular base 524 of the overcentre. However, due to the relatively large area of the circular base 524, the pressure compressing the fabric sheets 402, 408, 407, 409, 401, 412 is relatively small and there is not yet any electrical contact between the conducting layers 402, 407 and 401.

As the over-centre 521 is pressed down further the over-centre deforms until at a certain position it flips down to a second configuration as shown in *Figure 5D*. As in the case of *Figure 5C*, relatively little pressure is exerted onto the sheets 402, 408, 407, 409, 401, 412 below the circular base 524 of the over-centre device 521. However, the bump 522 acts on a relatively small area of the sheets 402, 408, 407, 409, 401, 412 and as a result it applies a relatively large pressure and produces a significant compression of said sheets. By this means the conductive sheets 402, 407 and 401 are brought into electrical contact at a single location 525.

Thus, using the over-centre device 521, the user of the alpha-numeric keyboard is provided with the two types of tactile feedback, as described with reference to *Figure 5*, while at the same time the bump 522 ensures that the electrical contact between conductive layers is focused on a single location determined by the positioning of the over-centre.

Using any of the above key registration devices provides an accurate and reliable positioning of compression of fabric at a key. Therefore, using these registration devices allows smaller key outlines to be used, without the user requiring a stylus to ensure accuracy of key depression. It should be noted that the key registration devices are thus locatable above or below the five fabric sensing layers 401, 409, 407, 408 and 402 and may be positioned

WO 01/75922

PCT/GB01/01425

14

within the outer fabric layers 410 and 412, as has been described, or alternatively they could be mounted outside of these layers, i.e. on the outside of all of the fabric layers.

The key registration devices described above, take the form of individual devices which are adhered to a fabric layer by a suitable adhesive. By using individual key registration devices with spaces between allows the complete alpha-numeric keyboard to be easily folded or similarly deformed. However, where flexing, folding etc. of the keyboard around tight radii is not an issue, a continuous flexible sheet containing all key registration devices of the alpha-numeric keyboard could be used instead.

Figure 6

A portion of the alpha-numeric keyboard, demonstrating the registration of the key registration devices, the printed keyboard outline and the conductive bands of layers 401 and 402 (shown in more detail in reference to *Figure 7*), is shown in *Figure 6*. The five conductive rows 601 to 605 of layer 402 and three of the conductive columns 606 to 608 of layer 401 are shown in *Figure 6*. Each intersection of a row and a column defines a separate region of the alpha-numeric keyboard, and each region corresponds to one of the QWERTY keys printed onto the top layer 410. For example, a key outline 609, corresponding to the key labelled "2", corresponds to the intersection of row 601 and column 606, and key outline 610, corresponding to the key labelled "R", corresponds to the intersection of row 602 and column 608.

Each key outline is arranged to be symmetrically positioned above a key registration device on layer 412. For example, key outline 609 is

WO 01/75922

PCT/GB01/01425

15

positioned symmetrically above key registration device 501.

As shown in *Figure 6*, the key outlines are arranged in a staggered manner, such that for the alpha-numeric keys, the centre of a key on one row is aligned with the gap between the keys on the row below. For example, key outline 609, is located such that its centre is aligned with the gap between key outlines 612 and 613. Therefore, the key outlines do not correspond exactly with the conductive band intersections. However, the key registration device for a particular key is located within the area defined by the key outline and the area defined by the corresponding conductive band intersection. Therefore, when a user presses a key, for example 609, because the key registration device (in this case 501) is located within the corresponding intersection of bands, (in this case bands 601 and 606) the conducting layers 401 and 402 are electrically connected at the correct intersection.

Figure 6 also shows key outline 614 and part of outline 615 corresponding to the "Alt" key and "Spacebar" respectively. Since they are keys of extended length, the respective key registration devices 616 and 617 are extended in a corresponding manner. Unlike devices 501 and 502, the key registration devices 616 and 617 are elongated with thicker cross-section side walls providing the tactile feedback function.

Figures 7A and 7B

The conductive layers 401 and 402 of *Figure 4* are shown separately in plan view in *Figures 7A* and *7B* respectively. *Figure 7A* shows layer 401 with conductive track assembly 404 having fifteen short attachment portions 701 to 715 attached along one edge of the fabric layer and conductive track assembly 405 having fifteen corresponding portions 701a to 715a attached

WO 01/75922

PCT/GB01/01425

16

along the opposing edge of the fabric layer **401**, effectively defining fifteen narrow conductive columns, for example columns **606**, **607**, **608**. In addition, the two longer attachment portions **721** of conductive track assembly **404** and **722** of conductive track assembly **405** define a wider conductive column

5 **716**. Accordingly, the layer **401** is effectively divided into a total of sixteen conductive columns, fifteen narrow columns and one wide column.

Figure 7B shows the five attachment portions **731** to **735** and **741** to **745** along opposing short sides of layer **402**, effectively defining the five parallel conductive rows, **601** to **605**.

10 The conductive fibres of each fabric layer **401** and **402** extend perpendicular to the attachment portions as previously described in reference to *Figures 2* and *3*. Therefore, in this way, the device is effectively divided into eighty (equal to 5x16) specific regions, each region is identifiable within the device as being in a particular column in sheet **401** and in a particular row in sheet

15 **402**. Furthermore, a mechanical interaction, corresponding to a key press, may result in a current flow within a particular area between conductive layers **401** and **402**.

Figure 8

20 An assembled alpha-numeric keyboard **801**, assembled from the layers shown in *Figure 4*, is shown in *Figure 8*. Wires are attached to the ends of the conductive tracks of conductive track assemblies **404**, **405**, **406** and **406a** and then assembled together in the form of a cable **802** connecting the fabric device **801** to an interface device **803**.

25 Physically, the alpha-numeric keyboard **801** appears to be a continuous sheet, without discontinuities. However, given the arrangement of

WO 01/75922

PCT/GB01/01425

17

electrical connectors, the sheet is effectively divided into a plurality of regions, a total of eighty in this example but the actual number present in any implementation is determined by the ultimate function that the alpha-numeric keyboard is to perform.

5 The device **801** is constructed from textile fabrics and as such it may be folded, flexed or wrapped around an object.

 The QWERTY keyboard outline **411** is shown in *Figure 8* to the left of the touch pad area **415**. In use the keyboard and interface circuit respond in a similar manner to a conventional computer keyboard, providing an output
10 indicative of which key or keys have been pressed. The touch pad is able to detect the X and Y position of a mechanical interaction on its surface and also the pressure applied by the mechanical interaction. Therefore, when the touch pad is touched by the user, they may, for example, manoeuvre a screen cursor by dragging their finger across the surface of the touch pad,
15 and then provide further information to the computer by pressing harder onto the touch pad. Therefore, the user may use the alpha-numeric keyboard of the present invention in place of the usual keyboard and in place of or in addition to a mouse or touch tablet or similar devices for inputting data into a computer or similar electronic device.

20 In order to enable the detection of a mechanical interaction and/or the pressure and location of that mechanical interaction within an area of the keyboard, the interface circuit **803** is configured to operate in different modes capable of providing the required outputs.

 In mode one operation, the interface circuit provides an output
25 indicating whether a mechanical interaction has occurred in a given area of the keyboard selected by the interface device. In mode two operation, the

09900299.13901

WO 01/75922

PCT/GB01/01425

18

5 circuit produces an output that provides a quantitative measure of the pressure and/or area of the mechanical interaction within an area of the keyboard selected by the interface circuit. In mode three operation, the circuit can provide an output corresponding to the pressure of the mechanical interaction and the X and Y positional co-ordinates at which the mechanical interaction occurred within a selected area (such as the touch pad area 415 of the fabric keyboard). In a fourth mode of operation, all inputs into the keyboard are selected in groups in a manner to be described later, and the position and pressure of a mechanical interaction may be determined
10 anywhere over the keyboard surface. To detect a key press on the keyboard, mode one or two operation is preferable. To detect the position of a mechanical interaction on a touch pad sensor, mode three or four operation is required with mode three (i.e. detecting the position and pressure within the touch pad area) being the most preferable in the embodiment of the keyboard shown in *Figure 8*.
15

Figure 9

Interface circuit 803 is detailed in *Figure 9*. The interface device includes a detection processor 901, a pressure/location detection circuit 902,
20 a switching circuit 903, a multiplex switch 904 having electrical connection inputs elements 905, an input socket 906 and an output socket 907 provided to allow connection to a computer. The computer may be, for example, a laptop, a PDA (personal digital assistant), or personal computer. Alternatively, the computer may be replaced by a mobile phone. Each of the five
25 conductive rows in layer 402, the fifteen narrow conductive columns in layer 401 and the wide column in layer 401 corresponding to the touch pad area,

WO 01/75922

PCT/GB01/01425

19

have two associated wires. Therefore in this embodiment with eighty regions, there is a total of forty two individual wires restrained within cable 802. These wires are received by input connector 906 and are then fed individually to the inputs elements 905 of multiplex switching circuit 904. It must be noted that in
5 modes one or two no connections to 701a and 715a along one edge of the keyboard are required and the number of electrical connections may therefore be twenty seven).

The interface circuit 803 must identify a press on the alpha-numeric keyboard as being a key press in the QWERTY keyboard area or a press on
10 the touch pad. If the QWERTY keyboard area is pressed, then the interface circuit provides an output identifying the location (identified by the multiplex scan of the regions) of the one or two keys which have been pressed (mode one or two operation). If the touch pad area is touched then the interface circuit provides an output indicating the location of the press and the pressure applied (mode three operation).
15

In the initial state, the multiplex switch 904, under the control of detection processor 901, connects the pressure/location detection circuit 902 to all five attachment portions 731 to 735 and a second connection to all five attachment portions 741 to 745 of layer 402. A further connection is made to
20 all sixteen attachment portions 701 to 715 and 721 on layer 401 with a final connection made to all sixteen attachment portions 701a to 715a and 722 on the opposite side of layer 401. A total of four connections to the pressure location detection circuit 902 are made. If, on viewing these terminals in a form described later as a z-axis measurement, an open circuit is present, no
25 mechanical interaction has occurred on the alpha-numeric keyboard. Alternatively, if a closed circuit is identified, this indicates the presence of a

WO 01/75922

PCT/GB01/01425

20

mechanical interaction and an output to this effect is supplied to switching circuit 903 which in turn conveys this information to the detection processor 901 and to output socket 907. This process is detailed further in relation to Figure 12.

5 A mechanical interaction could indicate one or more simultaneous key presses on the QWERTY keyboard outline 411 or a press on the touch pad area 415.

On detection of a mechanical interaction, the multiplex switch 904 under the control of detection processor 901, maintains the connections of the pressure/location detection circuit 902 to layer 402, and two connections are made from the pressure/location detection circuit 902 to the leftmost eight of the attachment portions 701 to 708 on one side of layer 401 and 701a to 708a on the opposite side of layer 401. Again the pressure/location detection circuit 902 detects the presence of a closed or open circuit; a closed circuit indicating one or more key presses in the leftmost half of the alpha-numeric keyboard. An output indicative of an open or closed circuit is supplied to the switching circuit 903 which in turn conveys this information to the detection processor 901 and to output socket 907.

The multiplex switching circuit is then commanded by the detection processor to disconnect the connection to the eight leftmost attachment portions of layer 401 and make connections from the pressure/location detection circuit 902 to the remaining seven short attachment portions 709 to 715 and 709a to 715a respectively. Again an open or closed circuit is detected and the information relayed to the detection circuit 901. A closed circuit at this stage indicates one or more key presses in the rightmost half of the QWERTY keyboard outline.

WO 01/75922

PCT/GB01/01425

21

In an alternative embodiment of the present invention, the multiplex switch **904**, under the control of detection processor **901**, makes a single connection between the pressure/location detection circuit **902** to all five attachment portions **731** to **735** with all five attachment portions **741** to **745** remaining unconnected. A second connection is made to all sixteen attachment portions **701** to **715** and **721** on layer **401** with all sixteen attachment portions **701a** to **715b** and **722** on the opposite side of layer **401** remaining disconnected. Accordingly, only two connections to the pressure/location detection circuit **902** are made. If, on viewing these terminals, an open circuit is present, no mechanical interaction has occurred on the alpha-numeric keyboard. Alternatively, if a closed circuit is identified, this indicates the presence of a mechanical interaction and an output to this effect is supplied to switching circuit **903** which in turn conveys this information to the detection processor **901** and to output socket **907**. In this example, the circuit is acting in mode one, and only a contact, or the absence of a contact is required to be indicated.

In the preferred embodiment, if no key presses are detected, therefore implying that the touch pad has been pressed, the detection processor provides an output to this effect to the output socket **907** via switching circuit **903**. The detection circuit also commands the multiplex switch **904** to make a connection of the pressure/detection location circuit **902** to attachment portion **721**, a second connection to portion **722**, a third connection to the five attachment portions **731** to **735** and a fourth connection to the five portions **741** to **745**. The pressure/location detection circuit detects pressure applied to the touch pad area **415** by a mechanical interaction such as a finger press and also the X and Y position of the mechanical interaction (mode three

WO 01/75922

PCT/GB01/01425

22

operation). Corresponding pressure and positional values are supplied by the pressure/location detection circuit (as described later in reference to *Figures 15 to 17*) to the switching circuit and so to the detection processor **901** and to the output socket **907**.

5 The connections to the pressure/location detection circuit **902** are maintained by the detection processor while the pressure location detection circuit provides an output indicative of a mechanical interaction. When a mechanical interaction is no longer indicated, the detection processor returns the multiplex switch back into the initial state.

10 Alternatively, if one or more key presses are detected relating to either the eight leftmost attachment portions **701** to **708** and **701a** and **708a** or the remaining short attachment portions **709** to **715** and **709a** and **715a**, then the detection processor **901** performs a binary search to identify the conducting row and column intersection at which a mechanical interaction is present.

15 The circuit does this by a process of elimination. For example, if a key press is not detected in the columns relating to attachment portions **709** to **715** and **709a** to **715a** then no further search is necessary in respect of these columns. But, if a key press is detected in the eight leftmost conducting columns relating to attachment portions **701** to **708** and **701a** to **708a**, the

20 multiplex switch **904** under the control of detection processor **901** makes connections from pressure/location detection circuit **902** to the first four attachment portions **701** to **704** and **701a** to **704a** of layer **401** and a further connection to the five attachment portions **731** to **735** and **741** to **745** on each side of layer **402**. Pressure/location detection circuit **902** detects the

25 presence of an open or closed circuit and provides an indicative output to detection processor **901**. The multiplex switch **904**, then makes a connection

WO 01/75922

PCT/GB01/01425

23

from pressure/location detection circuit 902 to the next four attachment portion 705 to 708 and 705a to 708a of layer 401 while maintaining the connections to the five attachment portions 731 to 735 and 741 to 745 of layer 402. The pressure/location detection circuit 902 detects the presence of an open or closed circuit and provides an indicative output to detection processor 901.

Thus, the control circuit identifies if just one or both of the two groups of four columns is subject to a key press. If just one of the two groups is identified as relating to a key press, then this group only is interrogated and the other group is eliminated from further search. But if both groups are identified as relating to a key press, then both groups will need to be interrogated further.

The process of binary search is continued in this manner until the identity of the individual columns relating to the key press or presses is established. A similar process is then followed to establish which of the rows contains the key press or presses. This is done by making connection of the location detection device to all sixteen attachment portions on both sides of layer 401 and a second connection to a varying number of the attachment portions 731 to 735 on layer 402. Having established both the row and the column, the detection processor 901 then provides an output indicating the location(s) to output socket 907 via the switching circuit 903. The detection processor then resets the multiplex switching circuit to its initial state in readiness for the next mechanical interaction to be detected.

25 **Figure 10**

5

10

15

25

WO 01/75922

PCT/GB01/01425

25

of the detector under investigation. A value of 10Kohms is typical for resistors **1008** and **1007**.

The PIC **1001** has an external crystal oscillator (not shown) running at 4 MHz connected across pins fifteen and sixteen. Positive five volts is supplied to pin fourteen and ground is connected to pin five. Pin four (the internal reset input) is held at positive five volts via a series resistor of 100ohms.

The program running on the PIC **1001** will determine the operational mode of the interface device **803** and determine the output measured by pressure/location detection circuit **902** within a region of the keyboard selected by the multiplex switch **904**.

The interface device **803** can function to provide outputs indicative of a mechanical interaction and to provide positional information about the location the mechanical interaction when, for example, the touch pad detection area is pressed. A mechanical interaction results in the initiation of current flow from the first electrically conductive layer **401** to the second electrically conductive layer **402**. Accordingly, the pressure/location detection circuit **902** is configured to detect the current flow and perform electrical measurements to determine properties of the interaction such as pressure and, in mode three operation, the position of the interaction occurring within a selected area.

Figures 11A and 11B

A procedure for determining the pressure and/or area of a mechanical interaction is detailed in *Figures 11A* and *11B*. An area of the conductive fabric layers **401** and **402** to which voltages are being supplied via

09980259 "110901

WO 01/75922

PCT/GB01/01425

26

multiplexing switch 904 are represented schematically by potentiometers 1101 and 1102 and the resistance of the conductive path between the outer layers at the location of the applied force is represented by variable resistor 803.

5 A first measurement of a characteristic of a mechanical interaction such as pressure is shown in *Figure 11A*. Five volts are applied to connector 1006, while connector 1005 remains disconnected. Connector 1003 is connected to ground via a resistor 1007 of known value. Thus current flows from connector 1006 through a first part of layer 402 as represented by a first
10 part 1104 of the potentiometer 1102, through the conductive path indicated by variable resistor 1103 having resistance R_v , through a first part of layer 401, indicated by a first part 1105 of potentiometer 1101 and through the known resistor 1007. The voltage, V_1 appearing at connector 1003 is measured and since this is equal to the voltage drop across resistor 1007, V_1
15 is directly proportional to the current flowing from connector 1006.

 A second measurement of R_v can be performed as shown in *Figure 11B*. Five volts are applied to connector 1004, while connector 1003 is disconnected. Connector 1005 is connected to ground via a resistor 1008 of known resistance. The voltage V_2 , dropped across resistor 1008 is
20 measured. Voltage V_2 is directly proportional to the current flowing through a second part of layer 401 indicated by a second part 1106 of potentiometer 1101, through the conductive path indicated by variable resistor 1103 having resistance R_v , through a second part of layer 402 indicated by a second part 1107 of potentiometer 1102 and through resistor 1008. It should be noted
25 that in mode one operation, where only an indication of a contact is required, only a first measurement (as indicated in *Figure 11A*) is required. Although

WO 01/75922

PCT/GB01/01425

27

less precise, a single measurement will provide an indication of the pressure applied that is sufficient for many applications (although a negligible position related error may occur). Hence, for the detection of key press on a keyboard a single pressure measurement would suffice.

5 For modes two, three and four, the sum of the resistance of first part 1105 and second part 1106 of potentiometer 1101 is approximately equal to the resistance between connector 1004 and 1003 on layer 401, and is therefore substantially constant during the measurements, since they occur in rapid succession. Similarly the sum of the resistance of first part 1104 and
10 second part 1107 of potentiometer 802 is approximately equal to the resistance between connector 1006 and 1007 on layer 402, and is also substantially constant during the measurements. As a result, the relationship 1110 exists between the resistance R_v , of the conductive path between the outer layers, and the measured voltages V_1 and V_2 , i.e. the resistance R_v
15 between the outer layers is proportional to the sum of the reciprocal of voltage V_1 and the reciprocal of voltage V_2 . For modes two, three and four, the voltages are used to calculate a Z value which is indicative of the pressure applied in the Z axis to the fabric planes. Depending upon the type of sensor used the resistance R_v depends upon area of the applied pressure
20 or a function of the area and the force as illustrated by relationship 811. Thus from the voltage measurements V_1 and V_2 an indication of the pressure with which the mechanical interaction is applied, or an indication of the area and the applied force may be determined.

25 **Figure 12**

WO 01/75922

PCT/GB01/01425

28

An example of the program running on the PIC 1001 of the pressure/location circuit 902 during mode one and two operation (where the circuit only produces an output in response to the pressure of a mechanical interaction) is detailed in *Figure 12*. At step 1201 the hardware is initialised and this process is detailed later in reference to *Figure 13*. At step 1202 the pressure/location detection circuit 902 measures values of voltages V1 and V2 (as described in reference to *Figure 11*) and calculates a Z value of the interaction. The details of step 1202 are described later with reference to *Figure 14*. At step 1203 a question is asked as to whether the Z data is greater than a predetermined value. If the answer to this question is no then the program returns to step 1202. Thus the circuit measures Z values until a Z value greater than a predetermined value is detected. If the answer to the question at step 1203 is yes then, in mode one operation, an output is produced that is indicative of a mechanical interaction at step 1204. In mode two operation, the circuit measures the necessary voltages and calculates a Z value at step 1204 and provides a quantitative output indicating the magnitude of the applied pressure.

Once an output has been provided, the program then returns to step 1202 and looks for an indication of a further mechanical interaction. For example, in mode two operation, the multiplexing switch 904 under the control of detection processor 901 will configure the connections made to the detector so that a further area of the detector is subsequently selected and the pressure/location detection circuit 902 will monitor that further area for an indication of a mechanical interaction.

25

WO 01/75922

PCT/GB01/01425

29

Figure 13

Step 1201 of *Figure 12* is shown in further detail in *Figure 13*. Within the initialisation step 1201, at step 1301 the interrupts are cleared and then at step 1302 pins seventeen and eighteen are set up as analogue to digital converter inputs. The microports of a PIC16C711 may be configured as low impedance outputs or high impedance inputs. When in high impedance input mode, pins seventeen and eighteen can be programmed to connect via an internal multiplexer, to the analogue to digital converter. At step 1303 the ports which are to be used as inputs or outputs are configured in their initial state. At step 1304 all system variables are cleared and all interrupts are disabled.

Figure 14

Step 1202 of *Figure 12* is shown in further detail in *Figure 14*. Within step 1202, at step 1401, the ports corresponding to pins two and ten are reconfigured as output ports and at step 1402 pin two is set to zero while pin ten is set to positive five volts. Thus connector 1003 is grounded via resistor 1007 and five volts are applied to connector 1006. At step 1403 a time delay, (typically of 200 microseconds in a sensor measuring 240 millimetres by 90 millimetres with an outer layer resistance of 3.5Kohms) is provided to allow voltages to settle before the voltage at pin seventeen is measured and stored as detailed in step 1404. Thus voltage V1 present at connector 1003 is measured and stored.

At step 1405 pins two and ten are reconfigured as high impedance inputs while pins one and twelve are reconfigured as low impedance outputs. At step 1406 the voltages the voltages on pins one and twelve are set to zero

WO 01/75922

PCT/GB01/01425

30

and positive five volts respectively. Thus connector **1005** is grounded via resistor **1008** while five volts are supplied to connector **1004**. A suitable time delay, equivalent to that at step **1403**, is provided at step **1407** before the voltage at pin eighteen is measured and stored at step **1408**. Thus the voltage present on connector **1005** is measured and stored as voltage V2. At step **1409** a Z value is calculated from stored voltages V1 and V2, and then stored. The pins one and twelve are reconfigured back to their initial state of high impedance inputs at step **1410**.

During mode three operation, the circuit is configured to detect whether a mechanical interaction has occurred within a region and to provide a calculation as to the position of the mechanical interaction (i.e. the x and y positional co-ordinates of an interaction) within an area of the keyboard under investigation (such as the touch pad), in addition to calculating a further property of the mechanical interaction, such as pressure and/or area. Similarly, in mode four operation all the connections within each conductive track assembly (i.e. **404**, **405**, **406** and **406a**) of the fabric planes **401** and **402** are connected so that the detector operates as a single pressure sensitive sheet with four single connections attached thereto. The x and y co-ordinates of a mechanical interaction on the detector are determined by the pressure/location detection circuit **902** in addition to determining a Z co-ordinate value as necessitated by mode two operation.

Figures 15A and 15B

A procedure for measuring pressure and/or area of a mechanical interaction (or Z axis data), is described in reference to *Figures 11A and 11B*. A procedure for determining the position of a mechanical interaction within an

WO 01/75922

PCT/GB01/01425

31

area of the detector under investigation is illustrated in *Figures 15A and 15B*.

Figure 15A details the application of a voltage to an area of fabric layer **401** which is represented as potentiometer **1101**. The corresponding area of fabric sheet **402** selected to detect an output voltage or have a voltage applied thereto is represented by potentiometer **1102**. A first position measurement is made by applying a voltage of five volts to connector **1005** whilst connector **1006** is grounded. As a result a potential gradient is produced across layer **1102**. A voltage measurement is made at connector **1003** using a high impedance device and so the voltage appearing on layer **1102** at the position of the applied force **1501** is determined. This voltage, V3 is directly proportional to the distance of the centre of the applied force from the electrical contact **1006** and indicates its x axis position.

A further measurement is shown in *Figure 15B*. Five volts are applied to connector **1003** and connector **1004** is grounded. A voltage measurement is made of voltage V4 appearing at connector **1005**. Voltage V4 is directly proportional to the distance of the centre of the applied force from the electrical contact connected to voltage input **1004** and indicates its Y axis position shown at **1502**. Therefore voltage V3 and V4 provide information as to the two dimensional position of the applied force on the sensor within the area of fabric sheets **401** and **402** under investigation, i.e. voltages V3 and V4 represent X and Y values for the centre of the position of the applied force.

Figure 16

An example of a program that runs on the PIC **701** to determine the location and pressure of a mechanical interaction (mode three and four

WO 01/75922

PCT/GB01/01425

32

operation) is shown in *Figure 16*. Steps **1201**, **1202** and **1203** have already been described in reference to *Figures 12, 13 and 14* as these steps are common to all four operational modes of the interface device **803**. Accordingly, the PIC is programmed to collect Z data (step **1202**) and to determine whether the collected Z data is greater than the pre-set lowest acceptable threshold value (step **1203**). In mode three operation, if the answer to the question at step **1203** is yes then the circuit measures voltages V1,V2,V3 and V4 (as described in reference to *Figures 11 and 15*) at step **1601**. Step **1601** is described later in more detail with reference to *Figure 17*.

At step **1602** a question is asked as to whether the calculated Z value is still above the predetermined value. If the question is answered in the affirmative, a further question is asked at step **1603** as to whether enough samples have been obtained. Typically, between three and ten sets of samples are taken, with lower numbers of sets of samples being taken when a fast response time is required. If the answer to the question at step **1603** is no, then the program returns to step **1602** and a further set of measurements are made. When the answer to the question at step **1603** is yes, or when the answer to the question at step **1602** is no, then the program calculates average values of the samples of the voltages V3 and V4, and of the values of Z which have been collected. Thus, the program measures a predetermined number of voltages before finding the average values, or if the Z value drops below a predetermined value, the average values are calculated immediately. By using the average of a number of samples the effect of mains power electromagnetic interference or other such environmental noise may be minimised.

0930099-12901

WO 01/75922

PCT/GB01/01425

33

A simple calculation to find an 'average' value for say the X value, is to find the median of the maximum and minimum values of the stored values V3. i.e. a 'smoothed' value for X is found by adding the maximum stored value of V3 to the minimum stored value of V3 and dividing the result by two.

5 To further improve accuracy, values of X, Y, and Z that differ by a large amount from their immediately preceding and immediately subsequent values are excluded from the calculations of the average. In addition, known methods of eliminating mains electricity supply interference may be applied to the signals received from the sensor.

10 At step 1605 the averaged values for V3 and V4 representing XY positional co-ordinates and the averaged values of the Z data are output at the serial communication output 1002. The program then returns to step 1202 and looks for an indication of further mechanical interactions.

15 **Figure 17**

Step 1601 of Figure 16 is shown in further detail in Figure 17. Within step 1601, at step 1701 a Z value is collected in the same manner as at step 1202. At step 1702 pins one and two are reconfigured as high impedance inputs and pins ten and eleven as low impedance outputs. At step 1703 pin 20 ten is set to zero volts and pin eleven is set to positive five volts. Thus five volts are supplied to connector 1005 while connector 1006 is grounded. A delay is then provided at step 1704, (of typically 200 microseconds for a device measuring 240mm by 90mm) to allow voltages in the sensor to settle before the voltage on pin seventeen is measured at step 1705. Therefore a 25 voltage V3 present on connector 1003 is measured which provides an indication of the X position of the applied force.

WO 01/75922

PCT/GB01/01425

34

Pins ten and eleven are then reconfigured as high impedance inputs and pins twelve and thirteen are reconfigured as low impedance outputs at step 1706. The voltage on pin twelve is then set to zero while the voltage on pin thirteen is set to five volts at step 1707. Thus five volts are supplied to connector 1003 while connector 1004 is grounded. A time delay is provided at step 1708, similar to that at step 1704, before the voltage appearing at pin eighteen is measured at step 1709. Thus a voltage V4 present on connector 1005 is measured which provides an indication of the Y position of the applied force. Pins twelve and thirteen are then reconfigured back to their initial state of high impedance inputs.

Therefore by the method described with reference to *Figures 11 to 17*, in mode three and mode four operation, the pressure/location detection circuit 902 is able to make voltage measurements V3 and V4 which provide an indication of the X and Y co-ordinate position of the force applied to a fabric sensor, and measure voltages V1 and V2 which are proportional to currents passing through the sensor and provide information as to a second characteristic of the applied force. The second characteristic may be the pressure with which the force is applied or a combination of the size of the force and the area. Furthermore, the pressure/location detection circuit 902 combines the voltages V1 and V2 to determine a Z value representative of the second characteristic.

Consequently, in both mode three and mode four operation, the pressure/location detection circuit 902 provides output data representative of X and Y position of the applied force and the Z value. However, in an alternative embodiment the pressure/location detection circuit 902 provides output data corresponding to the measured voltages V1, V2, V3 and V4.

WO 01/75922

PCT/GB01/01425

35

Figure 18

An alternative alpha-numeric keyboard **1801**, for use with a computer or similar electronic device, is shown in *Figure 18*. Unlike the device shown in *Figure 8*, the device **1801** does not have an area marked on its surface for use as a touch pad. Instead, it has a QWERTY keyboard outline **411** and a button outline **1802** printed onto its top insulating layer **1805**. The alpha-numeric keyboard may be used as a keyboard and, when the area defined by the button outline **1802** is pressed, the whole area of the keyboard outline may be used as a touch pad. A second press on the area within the button outline returns the alpha-numeric keyboard to its keyboard mode of operation.

Alternatively, the alpha-numeric keyboard does not have a "button" for changing the mode of operation between keyboard mode and touch pad mode. Instead, the device relies on software resident in the computer to recognise a distinctive movement of pressure traced out over its surface. That is, it recognises a gesture made by the user. Such gesture recognition is known, for example, in present palm computers.

The device **1801** contains conductive fabric layers and these are electrically connected to an interface circuit **1803** by means of a cable **1804**. The interface circuit **1803** has an output socket (not shown) suitable for connection to a computer or similar device.

Figure 19

The layered structure of the device **1801** is shown in the exploded view of *Figure 19*. The device has top and bottom conductive layers **1901**

WO 01/75922

PCT/GB01/01425

36

and **1902** to which electrical connections are made. Between layers **1901** and **1902** are central conductive layer **407** and non-conductive layers **408** and **409** which are of a similar construction to the corresponding layers of device **801**. The device **1801** also has a top insulating layer **1805** on top of its top conducting layer **1901**. The layers of device **1801** are arranged such that the keyboard outline **411** and button outlines **1802** and **1903** are all within an area defined by conducting attachment portions on layers **1901** and **1902**.

Figure 20

Conducting layers **1901** and **1902** of *Figure 19* are shown separately in *Figure 20*. The layers **1901** and **1902** have a construction similar to the conductive layers **401** and **402** of device **801**, except that each of layers **1901** and **1902** has only two electrical connections to the conductive fabric. Furthermore, the layers **1901** and **1902** are preferably conductive in all directions i.e. unlike layers **401** and **402**, layers **1901** and **1902** do not have unidirectional conductivity. Attachment portions **2001** and **2002** are located at the opposing longest sides of the layer **1901**, while attachment portions **2003** and **2004** are located on the opposing shortest sides of layer **1902**. Correspondingly, four conductive tracks **2005** to **2008** are provided to facilitate connection to the attachment portions. As shown in *Figure 14* the conductive tracks are configured such that one end of each of said tracks is close to the top right hand corner of its respective layer, thus easing the process of connection to cable **1804**.

The interface circuit **1803** provides an output indicative of the position and the pressure applied to the alpha-numeric keyboard by a mechanical interaction. In this embodiment only one region is defined by attachment

WO 01/75922

PCT/GB01/01425

37

portions **2001** to **2004** and there is no requirement for multiplexing by the interface circuit **1803**. Therefore, the interface circuit **1803** is of a similar type to pressure/location detection circuit **902** described with reference to *Figure 10*. In effect the interface circuit operates in mode four whereby the position and pressure of a mechanical interaction is determined anywhere on the keyboard surface. When connected to a computer or similar device the output provided by circuit **1803** is interpreted by software (or hardware) resident in the computer as a particular key press, button press, position or movement on the touch pad etc.

The alpha-numeric keyboard **1801** shown in *Figure 18* does not include key registration devices, however in an alternative embodiment key registration devices of one the types described with reference to *Figures 5, 5A, 5B or 5C and 5D* are included. In particular, where it is required to give the user of the keyboard the tactile feedback of positive key location and positive key depression while ensuring the repeated accurate location for fabric compression, key registration devices of the type shown in *Figure 5C and 5D* are preferred.

Figure 21

A further alternative embodiment of the present invention is shown in *Figure 21*. The alpha-numeric keyboard **2101** is connected to an interface circuit **2102** by a cable **2103**. The interface circuit **2102** also includes an output socket (not shown) for connection to a computer or similar device. The alpha-numeric keyboard and the interface circuit have a similar appearance to device **1801** and interface circuit **1803** of *Figure 18*, but have a different structure to them.

WO 01/75922

PCT/GB01/01425

38

Figures 22A and 22B

The alpha-numeric keyboard **2101** has the same layered structure as device **1801** except the conductive layers **1901** and **1902** are replaced by conductive layers **2201** and **2202** as shown in *Figures 22A and 22B*. The construction of the conductive layers **2201** and **2202** is similar to that of conductive layers **401** and **402** of alpha-numeric keyboard **801**, except the attachment portions of layer **2201** and **2202** have a different configuration. Layer **2201** has three short attachment portions **2203** to **2205** and a long attachment portion **2206** along one of the longest edges of the conductive fabric, and similar attachment portions **2207** to **2210** along the opposing edge. Conductive layers **2201** and **2202** are constructed to have unidirectional conductivity. Attachment portions **2203** to **2210** thus define three narrow conductive columns **2211** to **2213**, and wide conductive column **2214**. Layer **2202** has three narrow attachment portions **2215** to **2217** and a longer attachment portion **2218** along one of its shortest edges and similar attachment portions **2219** to **2222** along the opposing edge. The attachment portions **2215** to **2222** thus define three narrow conductive rows **2223** to **2225** and a wider conductive row **2226**. By this arrangement nine small regions are defined by the intersection of the narrow rows **2223** to **2225** and the three narrow columns **2211** to **2213**. The nine small regions are arranged to coincide with the individual keys in the left corner of the QWERTY keyboard that is nearest to the user. Therefore the keys for "control", "shift", "caps lock" and "alt" each correspond to one of the nine small regions. In addition seven larger regions are defined by the intersections of columns **2211** to **2214** and row **2226**, and by the intersections of column **2214** and rows **2223** to **2225**.

0990229 "11501
5620550

WO 01/75922

PCT/GB01/01425

39

In operation, the alpha-numeric keyboard **2101** may be used as a keyboard or as a touch pad in a similar manner to device **1801**. When operated as a touch pad the attachment portions on each of the four edges are connected together and connected to one of four connections on the pressure/location detection circuit **902** within circuit **2102**. The circuit then operates in mode three or four to determine the position and pressure of a mechanical interaction as described in *Figure 16*. The device then operates in a similar manner to the alpha-numeric keyboard **1801**.

However, when used as a keyboard the position of one or more key presses is determined both by a multiplexing process and by position location within the regions defined above. Therefore, the interface circuit **2102** has a similar structure to interface circuit **803** but operates in a different manner.

When used as a keyboard the interface circuit is connected to a computer or similar device by means of its socket. In operation, the interface circuit **2102** initially connects together all the attachment portions **2203** to **2206** on one edge of layer **2201**, and also connects together all the attachment portions **2215** to **2218** on the left edge of layer **2202** and looks for a closed circuit between the two sets of attachment portions. When a closed circuit is detected, the interface circuit **2102** disconnects the attachment portions **2206** and **2218**, and looks for a closed circuit between the three attachment portions **2203** to **2205** and the three attachment portions **2207** to **2209**.

If a closed circuit is detected this indicates that one or more of the nine keys in the bottom left hand corner of the keyboard has been pressed. In which case, the interface circuit **2102** performs a binary search in a similar manner to that performed by interface circuit **803** and hence determines

WO 01/75922

PCT/GB01/01425

40

which of the nine keys have been pressed. The circuit then provides an output to the computer indicative of the key or keys pressed.

If the interface circuit does not detect a closed circuit relating to the nine small regions, the interface circuit makes a connection from location/pressure detection circuit **902** to all attachment portions on one edge of layer **2201**, a second connection to all attachment portions on the opposing edge of layer **2201**, a third connection to all attachment portions on one side of layer **2202** and a fourth connection to all portions on the opposing edge of layer **2202**. The pressure/location detection circuit **902** then provides an output indicative of the location of the key press. This output is then interpreted by software in the computer as a particular key press or presses, in a similar manner to that described with reference to device **1801**.

Therefore, alpha-numeric keyboard **2101** requires less scanning than device **801**, having only four conductive rows and four conductive columns but provides separate rows and columns for the keys such as "control" and "shift" which are used in double key presses.

Figure 23

A further preferred embodiment of the present invention is illustrated in **Figure 23**. In this embodiment, a fabric alpha-numeric keyboard **2301** has a plurality of key registration devices **2302** protruding from its upper surface. Each of the key registration devices **2302** corresponds to a specific letter, numeral or function key as found on any standard keyboard.

Fabric keyboard **2301** has a flexible cable **2303** which extends from the top edge **2311** of the keyboard **2301** to the hand-held processor receiving assembly **2304**. The hand-held processor receiving assembly **2304** further

WO 01/75922

PCT/GB01/01425

41

comprises interface circuitry **2305** incorporated therein and foldable legs **2306** (which are shown in *Figure 23* in their closed position) and may be extended downwards to support the hand-held processor **2307** in an elevated position relative to the surface on which it is placed.

5 The hand-held processor **2307** is shown in *Figure 23* in the detached position. The processor comprises a screen **2309** and buttons **2310** via which an operator may interact with the hand-held processor to select, view and input data into the device. During use of the fabric keyboard **2301** the hand-held processor **2307** is located on the hand-held processor receiving
10 assembly **2304** which is configured to engage the lower edge of the hand-held processor **2307** to secure the processor in position. In this position, a connection is formed between the interface circuit and the serial input connections of the hand-held processor so as to facilitate data entry into the hand-held processor.

15 An example of a suitable hand-held processor device which could be used with the fabric keyboard **2301** of the present invention is a Palm^{RTM} Vx processor with an eight megabyte random access memory capacity manufactured by Palm Incorporated. It must be noted that when the hand-held processor **2307** is engaged with the hand-held processor receiver
20 assembly **2304** a connection between the output of the interface device **2305** and the hand-held processor **2307** is activated such that operations of the alpha numeric keyboard are directly communicated to the hand-held processor **2307**.

25 **Figure 24**

09550309.112501

WO 01/75922

PCT/GB01/01425

42

An exploded perspective view of the fabric keyboard **2301** illustrating the constituent layers that form the keyboard is shown in *Figure 24*. In the present embodiment of the invention, the fabric keyboard **2301** comprises ten individual constituent layers.

5 In common with all previously described embodiments, the fabric keyboard **2301** comprises a first electrically conductive fabric layer **2401** and a second electrically conductive fabric layer **2402**. Both of the electrically conductive fabric layers **2401** and **2402** have electrically conductive fibres woven or knitted together such that each conductive layer is capable of
10 conducting an electrical current in any direction along the plane of the layer rather than in a unidirectional manner as described in reference to *Figures 1* to 4.

The first electrically conductive layer **2401** has conductive tracks **2411** and **2412** forming an electrical contact along the left and the right edges of
15 the fabric keyboard respectively. Accordingly, a voltage gradient may be applied across the first electrically conductive layer **2401** between the right and left edges of the detector (i.e. in an X-axis direction). The second electrically conductive layer **2402** has conductive tracks **2413** and **2414** providing electrical contact along the top and bottom edges of the fabric layer
20 respectively. Accordingly a voltage may be applied across the second electrically conductive fabric layer **2402** in a direction perpendicular to that which a voltage is applied across the first electrically conductive layer **2401** (i.e. in the Y-axis direction).

The uppermost layer of the fabric keyboard is a continuous fabric layer
25 **2403** which has printed on its upper surface graphical representations corresponding to the alpha numeric keys of the keyboard. The graphical

WO 01/75922

PCT/GB01/01425

43

representations are preferably screen printed onto the fabric layer and, during the preferred construction process, the printing of the alpha-numerical graphical representations is performed once the fabric keyboard has been assembled. Furthermore, the fabric layer **2403** is preferably made from a stretchable or heat formable fabric so as to enable the fabric to be manipulated to receive the protrusions of the over centre moulding layer **2404**.

The over centre moulding layer **2404** is, in this embodiment, a continuous silicone rubber sheet having key registration device mouldings protruding on its upper surface. The key registration device mouldings protruding from the upper surface of layer **2404** are specifically moulded so as to align with the alpha numerical graphical representations shown on the uppermost layer **2403**. This layer will be described further in relation to *Figure 26*.

In the present embodiment, there are five layers located in between the first electrically conductive layer **2401** and the second electrically conductive layer **2402**. A first masking layer **2405** and a second masking layer **2406** contact the inner most surfaces of the electrically conductive layers **2401** and **2402** respectively. Both masking layers **2405** and **2406** are composed of a flexible tear resistant fabric with a laminate coating of polyurethane applied to a surface of the fabric. In an alternative embodiment, masking layers **2405** and **2406** are sheets of flexible polyurethane alone without any fabric constituent.

A series of circular holes **2415** have been punched through the masking layers **2405** and **2406**. Each of these holes is located so as to align with a corresponding key registration device moulding **2416** of layer **2404**.

WO 01/75922

PCT/GB01/01425

44

The function of the masking layers is described in more detail in reference to *Figure 26*.

Located in between the masking layers **2405** and **2406** are insulating mesh layers **408** and **409** which have previously been described in reference to *Figure 4*. Located between the insulating mesh layers **408** and **409** is a central conductive layer **407** which is configured to conduct an electric current from the first electrically conductive fabric layer **2401** to the second electrically conductive layer **2402** (i.e. in the Z axis direction) whilst substantially preventing any lateral current flow along the plane of the sheet (i.e. in the X and Y axis directions). The central conductive layer **407** has previously been described in more detail in reference to *Figure 4*.

A final fabric layer **2407** forms the under surface of the fabric keyboard. This layer is preferably a durable fabric cover configured to provide protection to the inner encapsulated layers of the fabric keyboard. In the preferred embodiment, the under surface of layer **2407** is laminated with patches of rubber to provide a high co-efficient of friction between the keyboard and any surface onto which the keyboard is placed.

The ten layers forming the fabric keyboard are mechanically secured into position by providing an adhesive around the perimeter edges of the constituent fabric layers.

Figures 25A and 25B

The first electrically conductive fabric layer **2401** is shown in more detail in *Figure 25A*. Two conductive tracks **2411** and **2412** form the electrical contacts with the conductive fibres of fabric layer **2401**. Conductive track **2411** contacts the left edge of fabric layer **2401** via attachment portion **2511**.

The second electrically conductive layer **2402** is shown in more detail in *Figure 25B*. Electrical connection is formed with the fabric layer **2402** by two conductive tracks **2413** and **2414**. Conductive track **2413** forms an electrical contact with the top edge of the electrically conductive fabric **2401** via attachment portion **2513**. Conduction portion **2523** extends over insulation strip **2502**, that extends along the top edge of the fabric layer, and enters the flexible cable **2303**. Conductive track **2414** forms an electrical connection with bottom edge of the fabric sheet **2402** via attachment portion **2514**. Conduction portion **2524** extends along the right edge of the fabric sheet and a portion of the top edge of the fabric sheet and enters into the flexible fabric cable **2303**. The conduction portion **2524** of conductive track **2414** is electrically insulated from the fabric layer by insulating strips **2502** which extends along the top edge and **2503** which extends along the right edge.

WO 01/75922

PCT/GB01/01425

46

Accordingly, voltages may be applied between the conductive tracks **2413** and **2414** so as to provide a voltage gradient across the electrically conductive fabric layer **2402** from top to bottom in the Y axis direction.

In this embodiment, only four connections are possible to the fabric keyboard, a single connection is formed to each of conductive tracks **2411** and **2412** of fabric layer **2401**, and a single connection is formed to each of conductive tracks **2413** and **2414** of layer **2402**. Accordingly, there is no specific requirement for the multiplexing interface circuitry detailed in reference to *Figure 6*. Alternatively, such circuitry may be present but remain permanently connected to the four possible electrical connections. In the preferred embodiment, the pressure/location detection circuit **902** is directly connected to the conductive tracks **2411**, **2412**, **2413** and **2414**. For example, connection **1003** and **1004**, as shown in *Figure 10* connect to conductive tracks **2411** and **2412** of layer **2401** respectively, and connection **1005** and **1006** connect to conductive tracks **2413** and **2414** of layer **2402**. In this configuration, the pressure of a mechanical interaction and the X and Y positional co-ordinates of a mechanical interaction are determined as described in reference to *Figures 11* to *17*.

Figures 26A and 26B

A portion of the fabric keyboard **2301** showing cross-section through a single key area of the fabric keyboard is shown in *Figure 26A* and *Figure 26B*. *Figure 26A* shows an illustration of a key in the absence of a mechanical interaction. The key registration device **2601** is moulded into the silicone rubber of the over centre moulding layer **2404**. Located underneath the over centre moulded layer **2404** is, in order of occurrence, the first

WO 01/75922

PCT/GB01/01425

47

electrically conductive fabric layer **2401**, the first mask layer **2405**, the first insulating mesh layer **408**, the central conductive layer **407**, the second insulating mesh layer **409**, the second mask layer **2406**, the second electrically conductive fabric layer **2402** and the lower fabric layer **2407**. In
5 contact with the upper surface of the over centre moulding layer **2404** is the upper fabric layer **2403**. A graphical representation of the letter, numeral or function to which the key registration device **2601** corresponds is printed onto the upper surface of fabric layer **2403** to directly coincide with the centre of the key registration device protrusion **2601**. The lower surface of the key
10 registration device protrusion **2601** has a contact protrusion **2602** extending towards the electrically conductive layer **2401**.

An operators' finger **503** is shown in *Figure 26A* forming an initial contact with the upper surface of the key registration device protrusion **2601**. Pressure is applied by the finger **503** to the key registration device protrusion
15 **2601** causing the key registration device to flex in a downward direction towards the first electrically conductive layer **2401** as shown in *Figure 26B*. The contact protrusion **2602** mechanically compresses the first electrically conductive layer **2401** into close contact with the first mesh layer **408** the central conductive layer **407**, the second mesh layer **409** and the second
20 electrically conductive fabric layer **2402**. It can be seen from *Figure 26B* that the key registration device **2601** and the associated contact protrusion **2602** are specifically aligned so as to facilitate a mechanical interaction bringing the electrically conductive layers closer together (as indicated at **2605**) through a hole in the first and second masking layers **2405** and **2406**. It should also be
25 noted that the depression of the key registration device by the operators finger and the resultant bend portions **2603** and **2604** provide tactile

09988888 113901
PCT/GB01/01425

WO 01/75922

PCT/GB01/01425

48

feedback to the users finger indicating the appropriate key on the fabric keyboard has been pressed.

The result of the mechanical interaction forcing the first electrically conductive layer **2401** and the second electrically conductive layer **2402** into close contact is that a voltage applied to either layer will result in a current flowing from one layer to another and enable electrical measurements to be made and the positional co-ordinates of the mechanical interaction to be determined as previously described. The positional co-ordinate data is supplied to the hand-held processor via the interface circuit. The hand-held processor subsequently correlates the X and Y positional co-ordinate data obtained at the point of the mechanical interaction with a series of look-up tables so that the corresponding data input function corresponding to the key pressed can be determined.

In this regard, the insulating masking layers **2405** and **2406** limit the areas within which a mechanical interaction may result in a current flowing between the first and the second electrically conductive layers **2401** and **2402**. Accordingly, an output will only be sent to the hand-held processor when a key is pressed and not following an accidental mechanical interaction at a point on the keyboard other than a key registration device. Therefore, the masking layers **2405** and **2406** prevent the transmission of ambiguous X and Y positional co-ordinate data correlating to positions around the pre-selected key registration devices and resulting in the correlation with a data input from the look-up table in response to an accidental mechanical interaction within the region around a key registration device.

The masking layers **2405** and **2406** are preferably thin layers (thickness of less than one millimetre) comprising holes having a diameter

WO 01/75922

PCT/GB01/01425

49

comparable to the diameter of the upper surface of the protrusion portion of the key registration device. This feature is particularly advantageous to allow for suitable tolerances for misalignments that may occur during assembly of the fabric keyboard. In an alternative embodiment, the masking layer **2405** and **2406** may be thicker to provide a greater separation between the first electrically conductive fabric layer **2401** and a the central conductive fabric layer **407** and prevent accidental contact during flexing of the keyboard. In such embodiments the insulating mesh layer **408** and **409** may be omitted.

In an alternative embodiment, the masking layers **2405** and may be omitted and the look-up tables of the hand-held processor device may be programmed to reduce the limits of acceptable variation with which the X and Y positional data of a mechanical interaction received is correlated with a specific out data input. For example an operator wishing to press the key corresponding to the letter "Q" will be required to provide a mechanical interaction having an X co-ordinate of fifteen (which corresponds to the centre of the "q" key registration device) with a lower acceptable variation of, for example, plus or minus three rather than plus or minus six. In addition, the look-up tables will require that the mechanical interaction corresponding for a "q" key press has a Y value of **200** (corresponding to the centre of the "Q" key registration device) with an acceptable variation limit of, for example, plus or minus ten rather than plus or minus twenty. In this embodiment it will be apparent that any mechanical interaction around the "Q" key which is outside the acceptable limits of the look-up table corresponding to the "Q" key will not result in an input indicative of the pressing of the "Q" key.

25

WO 01/75922

PCT/GB01/01425

50

Figure 27

Figure 27 illustrates an operator of the fabric keyboard **2301** located within a confined space of a briefcase **2702** supported on a table **2703**. Such a situation commonly occurs when an operator, such as a businessman, wishes to type material into a processor whilst in an out of office location. The fabric keyboard **2301** is conveniently located around other items of the briefcase **2702** and is connected to the hand held processor **2307** by the flexible cable **2303** and hand-held processor receiving assembly **2304**. Accordingly, the operator, by pressing keys of the keyboard **2301** can input data into the hand-held processor and the positional co-ordinates at which the key is pressed is correlated with a specific data entry which is displayed on the screen **2309** of the hand-held processor.

FIG. 27